Tim Carmichael
Agency Relations Manager
State Government Affairs

925 L Street, Suite 650
Sacramento, CA 95814
Tel: 916-492-4248
TCarmichael@semprautilities.com

January 17, 2017

Mr. Wes Ingram
California Air Resources Board
1001 "I" Street
Sacramento, CA 95812

Re: Written Comments by Southern California Gas Company and San Diego Gas & Electric Company on the Revised Proposed Short-Lived Climate Pollutant Reduction Strategy

Dear Mr. Ingram,

Southern California Gas Company (SoCalGas) and San Diego Gas & Electric Company (SDG&E) appreciate this opportunity to comment on the Revised Proposed Short-Lived Climate Pollutant Reduction Strategy (Revised Strategy). We offer these comments to enhance the Revised Strategy, as well as supplement input we provided on the Proposed Short-Lived Climate Pollutant Strategy[1].

I. Introduction and Summary

Our comments on renewable gas from organic waste streams are summarized below and further explained in the following pages:

- We support California Air Resources Board's (ARB) recognition of the opportunities and challenges of managing waste streams to reduce emissions of Short-Lived Climate Pollutants (SLCPs) and criteria pollutants while boosting economic growth in California. By putting organic waste to beneficial use, California can create value for renewable gas derived from these resources and enable significant mitigation of atmospheric methane emissions while simultaneously producing a flexible and reliable renewable energy resource.

- The overall collection and processing of biogas is necessary for California to meet its climate change and air quality goals. Injection of this collected resource into utility

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[1] SoCalGas and SDG&E Comments on the Proposed Air Resources Board Short-lived Climate Pollutant Reduction Strategy, May 2016. https://www.arb.ca.gov/lists/com-attach/90-slcp2016-AHNXPgBiBDZROwlu.pdf

pipelines for delivery to and use as a renewable energy resource by natural gas customers is a public benefit, and beneficial to all classes of ratepayers.[2] Therefore, additional interconnection facilities and pipelines necessary to achieve this public purpose should be considered utility infrastructure recoverable in rates from all customer classes by California utilities.

- Utilities can play a key role in the development of renewable gas resources by investing in pipelines and other infrastructure needed to produce renewable gas, connecting the projects to the gas pipeline system, and by developing vehicle refueling infrastructure. A Renewable Gas Standard (RGS) would drive investment by California utilities for renewable gas production, processing and pipeline interconnection.

- Renewable gas combined with low and ultra-low NOx engines provides the best opportunity for California to achieve in the near term its air quality and climate change goals in the on-road heavy-duty transportation sectors.

- Additionally, switching from diesel to natural gas or renewable gas to fuel off-road mobile sources has the potential to significantly reduce black carbon emissions. In the case of ocean-going vessels, switching from diesel fuel to liquid natural gas (LNG) would result in a reduction of 39% in black carbon. Switching from diesel fuel to LNG for line-haul locomotives reduce black carbon emissions by 87%.

II. Detailed Comments on Renewable Gas from Organic Waste Streams

SoCalGas and SDG&E support the goals of ARB's strategy of capturing biogas to be used as a transportation fuel, injected into natural gas pipelines, and/or used to generate on-site renewable electricity and heat[3]. Increasing the use of renewable gas as a transportation fuel would not only reduce methane emissions from organic waste streams, but also reduce black carbon by displacing diesel in heavy-duty vehicles.

SoCalGas and SDG&E also support the goals of SB 1383 to establish infrastructure development and procurement policies needed to encourage renewable gas projects. As called for in the SB 1383 timeline[4], we plan to coordinate with ARB, other state agencies and industry stakeholders to help ensure successful implementation of the final SLCP strategy.

A. Overcoming Renewable Gas Interconnection Challenges

As discussed in the Revised Strategy, there are challenges associated with interconnecting distributed sources of renewable energy onto the electricity grid or pipelines. High project startup costs, including the costs of connecting to the pipeline system, constitute one of the inherent challenges of renewable gas project development, regardless of feedstock. Interconnection with

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[2] AB 197 requires consideration of public benefits.
[3] Revised Proposed Short-Lived Climate Pollutant Strategy p. 66.
[4] Revised Proposed Short-Lived Climate Pollutant Strategy p. 14.

the pipeline system gives renewable gas access to the broadest market possible, facilitating the most diverse and flexible utilization opportunities and hence most dynamic and effective incentive strategies to encourage methane capture to achieve the objectives of the Revised Strategy and of SB 1383.

SoCalGas and SDG&E strongly support ARB's goals to address these challenges and build market certainty and value for renewable gas. We commend ARB for publishing a provisional Low Carbon Fuel Standard (LCFS) Carbon Intensity for dairy biogas that includes the benefit of avoided methane emissions. We believe this is a first step towards enhancing the project economics to produce renewable gas from dairy waste. We would support further examination of initiatives to incentivize the capture and use of biogas, particularly by offsetting infrastructure costs. Facilities that connect to the pipeline system are necessary for California to meet its climate change and air quality goals, and provide for the most long-term flexibility for this valuable renewable resource.

1. Renewable Gas Standard

Utilities can play a key role in the development of renewable gas resources by investing in infrastructure needed to produce renewable gas and connect the projects to the gas pipeline system. Under California's Renewable Portfolio Standard (RPS), electric utilities have upgraded transmission infrastructure to support increasing levels of electricity from wind and solar. These investments by the utilities have allowed CA to stay ahead of schedule for meeting the RPS requirements[5]. Similarly, a Renewable Gas Standard (RGS) and the ability to recover investment costs would drive investment in renewable gas production, processing and pipeline interconnection.

The Revised Strategy specifically identifies a feed-in tariff as a potential new policy to accelerate renewable gas project development[6]. However, an RGS that allows for market-based competition to prioritize cost-effective and high-impact resources could drive development of renewable gas from various sources more effectively than a feed-in tariff, which could limit competition to targeted sources and may only benefit limited sectors.

B. Renewable Natural Gas Can Transform the Freight Sector by Reducing GHGs and NOx

Near-zero natural gas technologies for both on-road and off-road sectors, when fueled by renewable gas, will help achieve the State's emissions targets. Because renewable gas is generated from organic waste sources, its use not only helps reduce transportation emissions, but can also reduce methane emissions that would otherwise be released into the air. When sourced from dairies and organic waste diverted from landfills, the carbon intensity of renewable gas is rated as "carbon-negative," due to avoided methane emissions from dairies and landfills.

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[5] California Energy Commission, http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf
[6] Revised Proposed Short-Lived Climate Pollutant Strategy p. 30.

SoCalGas and SDG&E urge ARB to integrate the policies needed to support regional air quality targets as well as the state's broader GHG targets as required by AB 197. Both the South Coast and San Joaquin Valley Air Basins must achieve significant reductions in nitrogen oxides ("NOx") to attain ozone and particulate matter National Ambient Air Quality Standards in the next decade. Eliminating GHG in the Heavy Duty Vehicle sector would have 5 times the impact on air quality compared with eliminating GHG from the electric sector.[7] From a cost effectiveness standpoint, targeted GHG reductions in the heavy duty vehicle sector is a highly efficient way to produce co-benefits in reducing smog-producing pollutants. Near-zero natural gas vehicles fueled by renewable gas in the heavy-duty Class 7 and 8 sectors can help these regions attain federal air quality standards as well as State GHG reduction goals with commercially ready technology available today.

As detailed in the Game Changer Technical Whitepaper prepared by Gladstein, Neandross & Associates ("GNA"), there is now a commercially-available heavy-duty natural gas engine that meets ARB's lowest-tier optional low-NOx emission standard at 0.02 g/bhp-hr NOx[8]. When paired with renewable gas, this technology will provide a commercially proven strategy to achieve major reductions immediately in emissions of criteria pollutants, air toxins, and GHGs. Since ARB has acknowledged that Class 7 and 8 heavy-duty electric and fuel cell electric vehicles will not be available until the 2030 timeframe,[9] renewable gas presents an immediate opportunity for California to achieve its air quality and climate change goals in those heavy-duty transportation sectors. Equally important, major reductions of toxic air contaminants and criteria pollutants can immediately be achieved in disadvantaged communities adjacent to freeways and areas of high diesel engine activity, where relief is most urgently needed and where AB 197 calls for GHG reductions that provide co-benefits.

The most powerful driver to produce renewable gas in today's market is to fuel California's Natural Gas Vehicles (NGVs), where renewable gas can support both California's LCFS and the Federal Renewable Fuel Standard (RFS) programs. According to the LCFS program, in the last half of 2015, the majority of NGV fuel in California was renewable gas – a huge success for this program. Growing the NGV market in California is not only an impactful and cost effective way to significantly reduce criteria pollutants and GHG emissions.

1. Dairy Biogas Pilot Projects

The development of infrastructure and biomethane projects at dairy and livestock operations is a key strategy in SB 1383, which calls for the development of at least five dairy biomethane

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[7] Brian Tarroja, PhD., Senior Research Scientist, Advanced Power and Energy Program, University of California, Irvine, "Transition to a Low-Carbon Economy: Air Quality Considerations," 2015 Integrated Energy Policy Report Workshop, July 24, 2015, slide 16.

[8] Game Changer Technical White Paper, Gladstein, Neandross & Associates, May 3, 2016. http://ngvgamechanger.com/pdfs/GameChanger_FullReport.pdf.

[9] See ARB Technology Assessment: Medium and Heavy Duty Battery Electric Trucks and Buses, October 2015, available at http://www.arb.ca.gov/msprog/tech/techreport/bev_tech_report.pdf and ARB Technology Assessment: Medium and Heavy-Duty Fuel Cell Electric Vehicles, November 2015, available at http://www.arb.ca.gov/msprog/tech/techreport/fc_tech_report.pdf

pipeline injection projects. SoCalGas is conducting education and outreach to developers to help accelerate renewable gas projects in this and other sectors. We believe that these projects would achieve several key objectives, such as demonstrating measureable progress towards California's sustainable freight targets within a 2030 timeframe. In addition, these projects would directly benefit the economically disadvantaged communities adjacent to these dairies and transportation corridors traveled by trucks fueled with renewable gas by reducing SLCP emissions and improving air quality. Extending natural gas infrastructure to these disadvantaged communities in conjunction with renewable gas pipeline interconnections could also present an opportunity to transition diesel and propane end-uses to cleaner burning natural gas appliances and vehicles.

III. Reducing Black Carbon Emissions in the Freight Sector

The Revised Strategy identifies off-road mobile sources as the biggest contributor to California's anthropogenic black carbon emission inventory. Switching from diesel to LNG or CNG to fuel off-road mobile sources has the potential to significantly reduce black carbon emissions. A recent report presented at the California Energy Commission estimates that eliminating 100% of the GHG in the Marine and Rail sectors (1.15% of total GHG in CA) would have eight times the impact on air quality compared with eliminating 100% of the GHG from the electric sector (9.5 % of total GHG in CA).[10] Again, from a cost effectiveness standpoint, targeted GHG reductions in the marine and rail sectors can have significant air quality co-benefits, especially near disadvantaged communities.

To demonstrate this point, Ramboll Environ estimated the potential emission reductions expected from the use of LNG in place of diesel fuel in ocean-going vessels and line-haul locomotives. The analysis uses an example route of a container ship making a one-way trip from Los Angeles to Shanghai, and a line-haul locomotive on a one-way trip from Los Angeles to Chicago. In the case of ocean-going vessels, switching from diesel fuel to liquid natural gas (LNG) would result in a reduction of 39% in black carbon prior to 2020. For calendar year 2020 and beyond, reductions in black carbon emissions increase from 230 pounds per one-way trip (or 39%) to 330 pounds per one-way trip (or 49%). Switching from diesel fuel to LNG for line-haul locomotives reduce black carbon emissions by 13 pounds per one-way trip or 87% reduction. Additional detail is provided in the following. Please refer to Appendix A for Ramboll Environ's approach to the analysis.

A. LNG-Fueled Ocean-Going Vessels Reduce Criteria Pollutants and Black Carbon Emissions

Emission estimates for an International Maritime Organization (IMO) Tier III diesel fueled 8,000 twenty-foot equivalent (TEU) ocean-going vessel (OGV) and a similar LNG OGV travelling from Los Angeles to Shanghai are shown in Table 1 (Appendix B). Two different estimates were made for the diesel OGV—one before 2020 and the other for 2020 and beyond to capture the

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[10] Brian Tarroja, PhD., Senior Research Scientist, Advanced Power and Energy Program, University of California, Irvine, "Transition to a Low-Carbon Economy: Air Quality Considerations," 2015 Integrated Energy Policy Report Workshop, July 24, 2015, slide 16.

change in emissions resulting from the switch in fuel oil sulfur content to 0.5% required by IMO Regulation 14. **The results show a reduction of 92% in PM_{10}, 85% in NO_X, >99% in SO_X, and 39% in black carbon prior to 2020.** For calendar year 2020 and beyond, we see a smaller reduction in PM_{10} of 69% due to the use of lower sulfur fuel oil; however, reductions in black carbon emissions increase from 230 pounds per one-way trip (or 39%) to 330 pounds per one-way trip (or 49%).

To understand the potential impact of such a fuel switch, consider a scenario of LNG OGVs increasingly replacing diesel OGVs for container cargo transport between Southern California and Asia. Southern California Association of Governments' (SCAG's) 2016-2040 Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) estimates that the Ports of Los Angeles and Long Beach will handle around 36 million TEUs in 2035[11]. More than 90% of this cargo (around 32.4 million TEUs) would be traffic to/from Asia[12]. If LNG OGVs started replacing diesel OGVs in 2020 and carried half of projected 2035 Asian cargo, black carbon emissions from OGVs would be reduced every year after introduction up to approximately 340 tons/year by 2035.

B. LNG-Fueled Line-Haul Locomotives Reduce Black Carbon Emissions

Emission estimates for a 100 rail car double-stacked intermodal container train powered by three Tier 4 diesel locomotives and a similar train powered by three LNG locomotives travelling from Los Angeles to Chicago are provided in Table 2. Both locomotives (diesel and LNG) meet the USEPA Tier 4 standard; as a result, there are no reductions in PM_{10} or NO_X for the LNG locomotives as compared to the diesel locomotive. We do however see a **13 pounds per one-way trip or 87% reduction in black carbon emissions with the use of LNG in place of diesel.**

Consider a scenario of LNG replacing diesel for freight trains from Southern California to and from the Midwest (e.g., Chicago). Historically, about 40% of the intermodal container cargo coming into the Ports of Los Angeles and Long Beach went to the Midwest/Chicago by rail. These ports are projected to handle container volumes of around 36 million TEUs in 2035[13] of which around 12.8 million TEUs are estimated to be transported by on- and off-dock intermodal trains[14]. If we assume that 40% of these TEUs travel to Chicago/Midwest region and a 100% of

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[11] SCAG. 2016 to 2040 RTP SCS - Transportation Goods Movement System Appendix, Adopted April 2016. Available at http://scagrtpscs.net/Documents/2016/final/f2016RTPSCS_GoodsMovement.pdf. Accessed May 2016.

[12] Fact sheets for Ports of Los Angeles and Long Beach. Available at: https://www.portoflosangeles.org/pdf/POLA_Facts_and_Figures_Card.pdf and http://www.polb.com/about/facts.asp. Accessed: May 2016.

[13] SCAG. 2016 to 2040 RTP SCS - Transportation Goods Movement System Appendix, Adopted April 2016.

[14] Per 2016 to 2040 RTP SCS, approximately 35.5% (5-year average 2010 to 2014) of container volumes handled by the Ports of Los Angeles and Long Beach are transported by intermodal trains.

these trains are LNG fueled[15], black carbon emissions would be reduced every year after the fuel switch up to approximately 85 tons/year by 2035.

IV. Conclusion

SoCalGas and SDG&E look forward to working with ARB, the other state agencies and industry stakeholders in the coming year in to help ensure successful implementation of SB 1383, AB 197, and ultimately achieving CA's 2030 GHG Reduction goals. We thank you for this opportunity to comment on the Revised Strategy, and we look forward to additional dialogue as the SLCP strategy is finalized. Please contact me if you have any questions or concerns about these comments.

Sincerely,

/s/_Tim Carmichael

Tim Carmichael
Agency Relations Manager
State Government Affairs

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[15] It is assumed that the railroads would do a nearly complete fuel switch by major line to minimize duplicating fueling infrastructure.

RAMBOLL ENVIRON

ENVIRONMENT
& HEALTH

MEMORANDUM

To: Jennifer Morris, Southern California Gas Company

From: Julia Lester, Ramboll Environ

Subject: **Emission Benefits of Use of Liquefied Natural Gas in Ocean Going Vessels and Line-Haul Locomotives**

Date May 25, 2016

Ramboll Environ
707 Wilshire Blvd.
Suite 4950
Los Angeles, CA 90017
USA

T +1 213 943 6300
F +1 213 943 6301
www.ramboll-environ.com

INTRODUCTION

Southern California Gas requested Ramboll Environ to estimate the potential emission reductions expected from use of liquefied natural gas (LNG) in place of diesel fuel in ocean-going vessels and line-haul locomotives. This analysis uses an example route of a container ship making a one-way trip from Los Angeles to Shanghai, and a line-haul locomotive on a one-way trip from Los Angeles to Chicago.

RESULTS

Ocean-Going Vessel (OGV)

Emission estimates for an IMO Tier III diesel fueled 8,000 twenty-foot equivalent (TEU) OGV and a similar LNG OGV travelling from Los Angeles to Shanghai are shown in Table 1. Two different estimates are made for the diesel OGV one before 2020 and the other for 2020 and beyond to capture the change in emissions resulting from the switch in fuel oil sulfur content to 0.5% required by IMO Regulation 14. The results show a reduction of 92% in PM_{10}, 85% in NO_X, >99% in SO_X, and 39% in black carbon prior to 2020. For calendar year 2020 and beyond we see a reduction smaller reduction in PM_{10} of 69% due to the use of lower sulfur fuel oil; however reductions in black carbon emissions increase from 230 pounds per one-way trip (or 39%) to 330 pounds per one-way trip (or 49%).

To understand the potential impact of such a fuel switch, consider a scenario of LNG OGVs increasingly replacing diesel OGVs for container cargo transport between Southern California and Asia. Southern California Association of Governments' (SCAG's) 2016-2040 Reginal Transportation Plan/Sustainable Communities Strategy (RTP/SCS) estimates that the Ports of Los Angles and Long Beach will handle around 36 million TEUs in 2035.[1] More than 90% of this cargo

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[1] SCAG. 2016 to 2040 RTP SCS - Transportation Goods Movement System Appendix, Adopted April 2016. Available at http://scagrtpscs.net/Documents/2016/final/f2016RTPSCS_GoodsMovement.pdf. Accessed: May 2016.

(around 32.4 million TEUs) would be traffic to/from Asia.[2] If LNG OGVs started replacing diesel OGVs in 2020 and carried half of projected 2035 Asian cargo, black carbon emissions from OGVs would be reduced every year after introduction up to approximately 340 tons/year by 2035.

Line-Haul Locomotive

Emission estimates for a 100 rail car double-stacked intermodal container train powered by three Tier 4 diesel locomotives and a similar train powered by three LNG locomotives travelling from Los Angeles to Chicago are provided in Table 2. Both locomotives (diesel and LNG) meet the USEPA Tier 4 standard; as a result, there are no reductions in PM_{10} or NO_X for the LNG locomotives as compared to the diesel locomotive. We do, however, see a 13-pound per one-way trip or 87% reduction in black carbon emissions with the use of LNG in place of diesel.

Consider a scenario of LNG replacing diesel for freight trains from Southern California to and from the Midwest (e.g., Chicago). Historically, about 40% of the intermodal container cargo coming into the Ports of Los Angeles and Long Beach goes to the Midwest/Chicago by rail. These ports are projected to handle container volumes of around 36 million TEUs in 2035[3] of which around 12.8 million TEUs are estimated to be transported by on-dock and off-dock intermodal trains.[4] If we assume that 40% of these TEUs travel to Chicago/Mid-West region and a 100% of these trains are LNG fueled,[5] black carbon emissions would be reduced every year after the fuel switch up to approximately 85 tons/year by 2035.

ANALYSIS APPROACH

Ocean-Going Vessel (OGV)

OGV container ships usually use slow speed diesel engines for the main propulsion. Auxiliary power for the OGV's electrical needs are supplied either by auxiliary engines or a shaft generator connected to the main propulsion engine. In order to simplify this analysis, Ramboll Environ assumed that the auxiliary power would be supplied by the main propulsion engine.

The equation used to estimate the emissions of an OGV travelling from Los Angeles to Shanghai is provided below:

$$\textbf{OGV Emissions (tons/trip)} = \textbf{Engine Load (kW)} \times \textbf{Transit Time (hr/trip)} \times \textbf{Emission Factor (g/kW-hr)} \div \textbf{907,184.7 (g/ton)}$$

Emission factors used in this analysis are provided in Table 3. From January 1, 2016, OGVs are required to meet the International Maritime Organization (IMO) Tier III oxides of nitrogen (NO_X) standard of 3.4 g/kW-hr while operating within the North American Emission Control Area (ECA). Once outside the ECA, the OGV can operate at the Tier II NO_X standard of 14.4 g/kW-hr. For purposes of this analysis, Ramboll

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[2] Fact sheets for Ports of Los Angeles and Long Beach. Available at: https://www.portoflosangeles.org/pdf/POLA_Facts_and_Figures_Card.pdf and http://www.polb.com/about/facts.asp. Accessed: May 2016.

[3] SCAG. 2016 to 2040 RTP SCS - Transportation Goods Movement System Appendix, Adopted April 2016.

[4] Per 2016 to 2040 RTP SCS, approximately 35.5% (5-year average 2010 to 2014) of container volumes handled by the Ports of Los Angeles and Long Beach are transported by intermodal trains.

[5] It is assumed that the railroads would do a nearly complete fuel switch by major line to minimize duplicating fueling infrastructure.

Environ has assumed that the propulsion engine will operate a NO_X control technology like selective catalytic reduction to achieve the IMO Tier III standard while operating within the North American ECA.

Based on IMO Regulation 14, the sulfur content of fuel oils used on OGVs are required to be below 0.1% while operating inside the North America ECA. While operating in open sea (outside ECA), fuel oil sulfur content has to be maintained below 3.5%. Ramboll Environ has assumed a fuel oil sulfur content of 2.5% for this analysis. After 2020, OGVs will be required to use fuel oils with a sulfur content below 0.5%. Emission factors for particulate matter less than 10 microns (PM_{10}) and oxides of sulfur (SO_X) were obtained from California Air Resources Board's (CARB's) reference document titled "Emissions Estimation Methodology for Ocean-Going Vessels."[6]

Criteria air pollutant (PM_{10}, NO_X, and SO_X) emission factors for liquefied natural gas (LNG) OGVs were obtained from a scientific report published by the Norwegian Institute of Air Research.[7]

Emission factors for black carbon were estimated as the elemental carbon factor of PM_{10}. CARB[8] and United Stated Environmental Agency (USEPA)[9] speciation factors were used to estimate black carbon emission factors for various fuel types.

Emission estimates for an OGV travelling from Los Angeles to Shanghai were made for an 8,000 twenty-foot equivalent (TEU) OGV traveling at a speed of 25 knots. Transit time for the one-way trip was estimated based on vessel speed and total trip distance[10] of 5,708 nautical miles (nm). Trip distance within the North America ECA is around 200 nm.

Line-Haul Locomotive

Line-haul locomotives are used to move containers and bulk freight cross-country. Emissions from line-haul locomotives depend on the fuel efficiency, gross weight of the train, and mileage. The following equations were used to estimate the emissions from a line haul travelling from Los Angeles to Chicago:

$$\textbf{Locomotive Emissions (tons/trip)} = \textbf{Energy Consumption (bhp-hr/trip)} \times \textbf{Emission Factor (g/bhp-hr)} \div \textbf{907,184.7 (g/ton)}$$

$$\textbf{Energy Consumption (bhp-hr/trip)} = \textbf{Gross Weight of Train (gross ton)} \times \textbf{Track Mileage (miles/trip)} \div \textbf{Fuel Productivity Factor (gross ton-mile/diesel gallon)} \times \textbf{20.8 (bhp-hr/diesel gallon)}$$

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[6] Available at: http://www.arb.ca.gov/regact/2011/ogv11/ogv11appd.pdf. Accessed: May 2016.

[7] Norwegian Institute of Air Research. Pollutant emissions from LNG fueled ships. Available at: https://brage.bibsys.no/xmlui//bitstream/id/378709/17-2015-sla-Deliverable_Emission_Factors_LNGships_v2.pdf. Accessed: May 2016.

[8] CARB's speciation profiles for PM4251, PM1191, and PM4252 OGVs are used to estimate black carbon emission factors for IMO Tier III slow speed engine operating on 0.1%, 2.5%, and 0.5% sulfur fuel oils respectively. Available at: http://www.arb.ca.gov/ei/speciate/speciate.htm. Accessed: May 2016.

[9] USEPA's speciation profiles for CNG buses is used to estimate black carbon emission factors for the LNG engine. Available at: https://www3.epa.gov/otaq/models/moves/documents/420r15022.pdf. Accessed: May 2016.

[10] Transit distance estimates were obtained from http://www.sea-distances.org/. Accessed: May 2016.

USEPA Tier 4 emission standards for locomotives went into effect in calendar year 2015. As a result, this analysis compares the emissions from a Tier 4 locomotive with LNG locomotive. There is very limited data available for emission factors from diesel Tier 4 (one General Electric [GE] Tier 4 engine model certification data) and LNG locomotives (one GE LNG locomotive engine model). These are presented in Table 4. Both locomotives meet USEPA Tier 4 standard, however the LNG locomotive has slightly higher NO_X emissions as compared to the diesel locomotive. USEPA[11] speciation factors were used to estimate black carbon emission factor, which are assumed to be the elemental carbon fraction of PM_{10}.

A train's gross tonnage depends upon the number of rail cars, mass of freight carried, and the number of locomotives. The type of freight train chosen for this analysis is a 100 rail car double-stacked intermodal container train powered by three locomotives. Gross weight for this train was estimated to be 5,979 tons (Table 2). The track mileage along the BNSF route from Los Angeles to Chicago was estimated using BNSF's Division Maps[12] with detailed mile posts. CARB's estimates for fuel productivity factor[13] for line-haul locomotive travelling in California of 640 gross ton- miles per diesel gallon were used to estimate the energy consumption for the trip.

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[11] USEPA's speciation profiles for heavy-heavy duty diesel trucks without diesel particulate filter and CNG buses were used to estimate black carbon emission factors for the diesel and LNG locomotives. Available at: https://www3.epa.gov/otaq/models/moves/documents/420r15022.pdf. Accessed: May 2016.

[12] Available at: http://www.bnsf.com/customers/where-can-i-ship/maps/. Accessed: May 2016.

[13] CARB. 2014. Locomotive Inventory Update. November 7. Available at: http://www.arb.ca.gov/msei/goods_movement_emission_inventory_line_haul_octworkshop_v3.pdf. Accessed: May 2016.

ATTACHMENT A
TABLES

Table 1. Emission Estimates for an Ocean Going Vessel Travelling from Los Angeles to Shanghai

Southern California Gas Company
Los Angeles, California

Propulsion Engine	Operating Year	Mass Emissions[1] (tons/trip)			
		PM_{10}	NO_X	SO_X	Black Carbon
IMO Tier III Slow Speed Engine	2016 to 2019	21.9	211.2	152.9	0.29
	2020 and beyond	5.7	211.2	27.8	0.34
LNG Engine	2016 and beyond	1.7	32.4	0.008	0.18

Operating Year	Emission Benefits of Using an LNG Engine[2] (% Reduction)			
	PM_{10}	NO_X	SO_X	Black Carbon
2016 to 2019	92%	85%	99.99%	39%
2020 and beyond	69%	85%	99.97%	49%

Notes:

[1] Mass emissions are estimated using the maximum continuous rating of a 8,000 TEU ocean going vessel (OGV) operating at 25 knots, the transit time for a one-way trip from Los Angeles to Shanghai, and the emission factors shown in Table 3.

[2] Emission benefits are estimated as a percentage difference between the LNG engine mass emissions and the IMO Tier III slow speed engine mass emissions.

[3] Maximum continuous rating of a 8,000 TEU ocean going vessel (OGV) operating at 25 knots was obtained from the document titled "Propulsion of 8,000-10,000 teu Container Vessel" published by MAN Diesel & Turbo. Available at: http://marine.man.eu/docs/librariesprovider6/technical-papers/propulsion-of-8-000-10-000-teu-container-vessel.pdf?sfvrsn=10. Accessed: May 2016.

[4] Transit distance estimates were obtained from http://www.sea-distances.org/. Accessed: May 2016.

[5] Transit time was estimated using transit distance and OGV travel speed.

Constants:

Maximum Continuous Rating at 25 knots[3]	59,880	kW
OGV Travel Speed	25	knots
Transit Distance[4]	5,708	nm
Within North American ECA	200	nm
Outside North American ECA	5,508	nm
Transit Time[5]	228.32	hr
Within North American ECA	8	hr
Outside North American ECA	220.32	hr

Conversion Factor:

907184.7 g/ton

Abbreviations:

% - percentage
ECA - Emission Control Areas
g - grams
hr - hour
IMO - International Maritime Organization
knot - nautical miles per hour
kW - kilowatt
LNG - liquefied natural gas
nm - nautical miles
NO_X - oxides of nitrogen
OGV - ocean going vessels
PM_{10} - particulate matter less than 10 microns in diameter
SO_X - oxides of sulfur
TEU - twenty foot equivalent

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Table 2. Emission Estimates for a Train Traveling from Los Angeles to Chicago

Southern California Gas Company
Los Angeles, California

Engine	Mass Emissions[1] (tons/trip)		
	PM_{10}	NO_X	Black Carbon
Tier 4 Diesel Locomotive	0.0096	0.48	0.008
LNG Locomotive	0.0096	0.58	0.001

Emission Benefits of Using an LNG Engine[2] (% Reduction)		
PM_{10}	NO_X	Black Carbon
0%	-20%	87%

Notes:

[1] Mass emissions are estimated using energy consumption for a one-way trip (shown under sub-heading "constants" below) from Los Angeles to Chicago and emission factors shown in Table 4.

[2] Emission benefits are estimated as a percentage difference between the LNG locomotive engines mass emissions and diesel Tier 4 locomotive engines mass emissions.

[3] Train gross weight is estimated for a 100 stack car train carrying double-stacked forty foot equivalent containers on each stack car, powered by three locomotives.

[4] The weight for a locomotive was obtained from the product specification sheet for the GE Evolution Series Tier 4 Locomotive. Available at: http://media.getransportation.com/sites/default/files/3%20EvoSeries%20Tier%204_locomotives.pdf . Accessed: May 2016.

[5] Mass of a stack car was obtained from the BNSF Glossary of Railroad Terminology and Jargon. Available at: https://www.bnsf.com/customers/pdf/glossary.pdf. Accessed: May, 2016.

[6] Average weight for a forty foot equivalent container (empty and full) was estimated based on the 2015 container statistics from Port of Oakland. Available at: http://www.portofoakland.com/port/seaport/facts-and-figures/. Accessed: May 2016

[7] Diesel fuel productivity factor for California was obtained from ARB's Locomotive Inventory Update dated November 7, 2014. Available at: http://www.arb.ca.gov/msei/goods_movement_emission_inventory_line_haul_octworkshop_v3.pdf. Accessed: May 2016.

[8] Track mileage was estimated based on the track mileage along the BNSF route from Los Angeles to Chicago using BNSF's Division Maps with detailed mile posts. Available at: http://www.bnsf.com/customers/where-can-i-ship/maps/. Accessed: May 2016.

[9] Diesel fuel consumption was estimated using the gross weight of the train, fuel productivity factor, and track mileage.

[10] Energy consumption for a one-way trip from Los Angeles to Chicago was estimated by converting the diesel fuel consumption with the USEPA's conversion factor of 20.8 bhp-hr/gal diesel for large line-haul locomotives. USEPA's conversion factor is available at: https://www3.epa.gov/nonroad/locomotv/420f09025.pdf. Accessed: May 2016.

Train Gross Weight Estimate[3]:

Train Component	Number of Components	Mass of Each Component (ton)
Locomotive[4]	3	213
Train Car[5]	100	27.2
Forty Foot Equivalent Containers[6]	200	13.1
Gross Weight of the Train		**5,979**

Constants:

Diesel Fuel Productivity Factor[7]	640	gross ton-miles/diesel gal
Track Mileage[8]	2247.5	miles
Diesel Fuel Consumption[9]	20,997	diesel gal
Energy Consumption[10]	436,729	bhp-hr

Conversion Factors:

907184.7	g/ton
20.8	bhp-hr/diesel gal

Abbreviations:

% - percentage
bhp - brake horse power
g - grams
gal - gallon
hp - horsepower
hr - hour
LNG - liquefied natural gas
NO_X - oxides of nitrogen
PM_{10} - particulate matter less than 10 microns in diameter
USEPA - United States Environmental Protection Agency

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Table 3. Ocean Going Vessel Emission Factors

Southern California Gas Company
Los Angeles, California

Propulsion Engine Type	Operating Details	Fuel Type	Emission Factors (g/kW-hr)			
			PM_{10} [1,2]	NO_X [3,2]	SO_X [1,2]	Black Carbon [4,5]
IMO Tier III Slow Speed Engine	Within North American Emission Control Area (ECA)	Marine Distillate 0.1% Sulfur[6]	0.25	3.4	0.36	0.013
	Outside ECA before January 1, 2020	Heavy Fuel Oil 2.5% Sulfur[7]	1.50	14.4	10.50	0.020
	Outside ECA after January 1, 2020	Marine Distillate 0.5% Sulfur[8]	0.38	14.4	1.90	0.023
LNG Engine	All operation	LNG	0.115	2.15	0.00051	0.012

Notes:

[1] PM_{10} and SO_X emission factors for the IMO Tier III Slow Speed Engine were obtained from California Air Resources Board's May 2011 reference document titled "Emissions Estimation Methodology for Ocean-Going Vessels." Available at: http://www.arb.ca.gov/regact/2011/ogv11/ogv11appd.pdf. Accessed: May 2016.

[2] PM_{10}, NO_x, and SO_X emission factors for the LNG engine were obtained from the scientific report, "Pollutant emissions from LNG fuelled ships" published by the Norwegian Institute of Air Research. Available at: https://brage.bibsys.no/xmlui//bitstream/id/378709/17-2015-sla-Deliverable_Emission_Factors_LNGships_v2.pdf. Accessed: May 2016.

[3] NO_x emission factors for the IMO Tier III Slow Speed Engine are assumed to be equal to the IMO Regulation 13 Tier III standard of 3.4 g/kW-hr while operating within the North American ECA and IMO Regulation 13 Tier II standard of 14.4 g/kW-hr while operating outside ECA. Note, ocean going vessels (OGVs) are required to meet the Tier III standard only while operating inside the ECA. For purposes of this analyses Ramboll Environ has assumed that the slow speed engine will have a NO_X control technology like an selective catalytic reduction (SCR) unit that operates only when the OGV is within the ECA.

[4] For purposes of this analyses elemental carbon is used as a surrogate for black carbon. CARB's speciation profiles for PM4251, PM1191, and PM4252 OGVs are used to estimate black carbon emission factors for IMO Tier III slow speed engine operating on 0.1%, 2.5%, and 0.5% sulfur fuel oils respectively. Available at: http://www.arb.ca.gov/ei/speciate/speciate.htm. Accessed: May 2016.

[5] For purposes of this analyses elemental carbon is used as a surrogate for black carbon. EPA's speciation profiles for CNG buses is used to estimate black carbon emission factors for the LNG engine. Available at: https://www3.epa.gov/otaq/models/moves/documents/420r15022.pdf. Accessed: May 2016.

[6] IMO Regulation 14 requires OGVs to use fuel oils with a sulfur content ≤0.10% mass by mass (m/m) while operating within the North American Emission Control Areas (ECA), nominally 200 nautical miles out from the USA and Canadian west coast.

[7] IMO Regulation 14 requires OGVs to operate on fuel oils with a sulfur content ≤3.50% m/m while operating outside ECA. For purposes of this analyses Ramboll Environ has assumed the use of heavy fuel oil with a nominal sulfur content of 2.5% while operating outside ECA.

[8] IMO Regulation 14 requires OGVs to operate on fuel oils with a sulfur content ≤0.50% m/m while operating outside ECA on and after January 1, 2020. Depending on the outcome of a review as to the availability of the required fuel oil, this date could be deferred to 1 January 2025.

Black Carbon Speciation Factors:

Fuel	Speciation Profile	Elemental Carbon / PM_{10}
Marine Distillate 0.1% Sulfur	CARB PM4251[4]	0.052
Heavy Fuel Oil 2.5% Sulfur	CARB PM1191[4]	0.013
Marine Distillate 0.5% Sulfur	CARB PM4252[4]	0.061
LNG	Average of EPA Profiles 95220 and 95219[5]	0.102

Abbreviations:

% - percentage
ECA - Emission Control Areas
g - grams
hr - hour
IMO - International Maritime Organization
kW - kilowatt
LNG - liquefied natural gas
NO_X - oxides of nitrogen
OGV - ocean going vessels
PM_{10} - particulate matter less than 10 microns in diameter
SO_X - oxides of sulfur

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Table 4. Locomotive Emission Factors
Southern California Gas Company
Los Angeles, California

		Emission Factors (g/hp-hr)		
Engine Type	**Fuel Type**	**PM$_{10}$ [1,2]**	**NO$_X$ [1,2]**	**Black Carbon [3,4]**
Tier 4 Diesel	Diesel	0.02	1.0	0.016
LNG Engine	LNG	0.02	1.2	0.002

Notes:

[1] PM$_{10}$ and NO$_X$ emission factors for the locomotive were obtained from USEPA engine certification 2015 data for a Tier 4 locomotive (engine family FGETK0958T3A, model ET44AC/C4). Available at: https://www3.epa.gov/otaq/certdata.htm#locomotive. Accessed: May 2016.

[2] PM$_{10}$, and NO$_x$ emission factors for the LNG engine were obtained from the GE NextFuel^{TM} presentation slides, "NextFuelTM Natural Gas" published by the GE on September 3, 2014.

[3] For purposes of this analyses elemental carbon is used as a surrogate for black carbon. EPA's speciation profiles for diesel heavy-heavy-duty truck without diesel particulate filter is used to estimate black carbon emission factors for the locomotives. Available at: https://www3.epa.gov/otaq/models/moves/documents/420r15022.pdf. Accessed: May 2016.

[4] For purposes of this analyses elemental carbon is used as a surrogate for black carbon. EPA's speciation profiles for CNG buses is used to estimate black carbon emission factors for the LNG engine. Available at: https://www3.epa.gov/otaq/models/moves/documents/420r15022.pdf. Accessed: May 2016.

Black Carbon Speciation Factors:

Fuel	**Speciation Profile**	**Elemental Carbon / PM$_{10}$**
Diesel	EPA Profile 8995	0.7897
LNG	Average of EPA Profiles 95220 and 95219[4]	0.102

Abbreviations:

% - percentage
ECA - Emission Control Areas
g - grams
hr - hour
IMO - International Maritime Organization
kW - kilowatt
LNG - liquefied natural gas
NO$_X$ - oxides of nitrogen
OGV - ocean going vessels
PM$_{10}$ - particulate matter less than 10 microns in diameter
SO$_X$ - oxides of sulfur

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